

DESIGN OF AN EXHAUST GAS
CALORIMETER FOR AUTOMOBILE ENGINES

BY

J. L. MAYER

L. E. HIBBARD

ARMOUR INSTITUTE OF TECHNOLOGY

1915

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Design of an exhaust gas
calorimeter for automobile

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$$V_0 = \left(1 - \frac{R}{\rho_{\rm max}}\right) V_{\rm max}$$

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**DESIGN OF AN EXHAUST GAS
CALORIMETER FOR AUTO-
MOBILE ENGINES**

A THESIS

PRESENTED BY

J. LEO MAYER
LEWIS E. HIBBARD

TO THE
PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

MECHANICAL ENGINEERING

MAY 27, 1915

G.T. Hibbardt 5/25/15

J.M. Raymond
L.C. Monin



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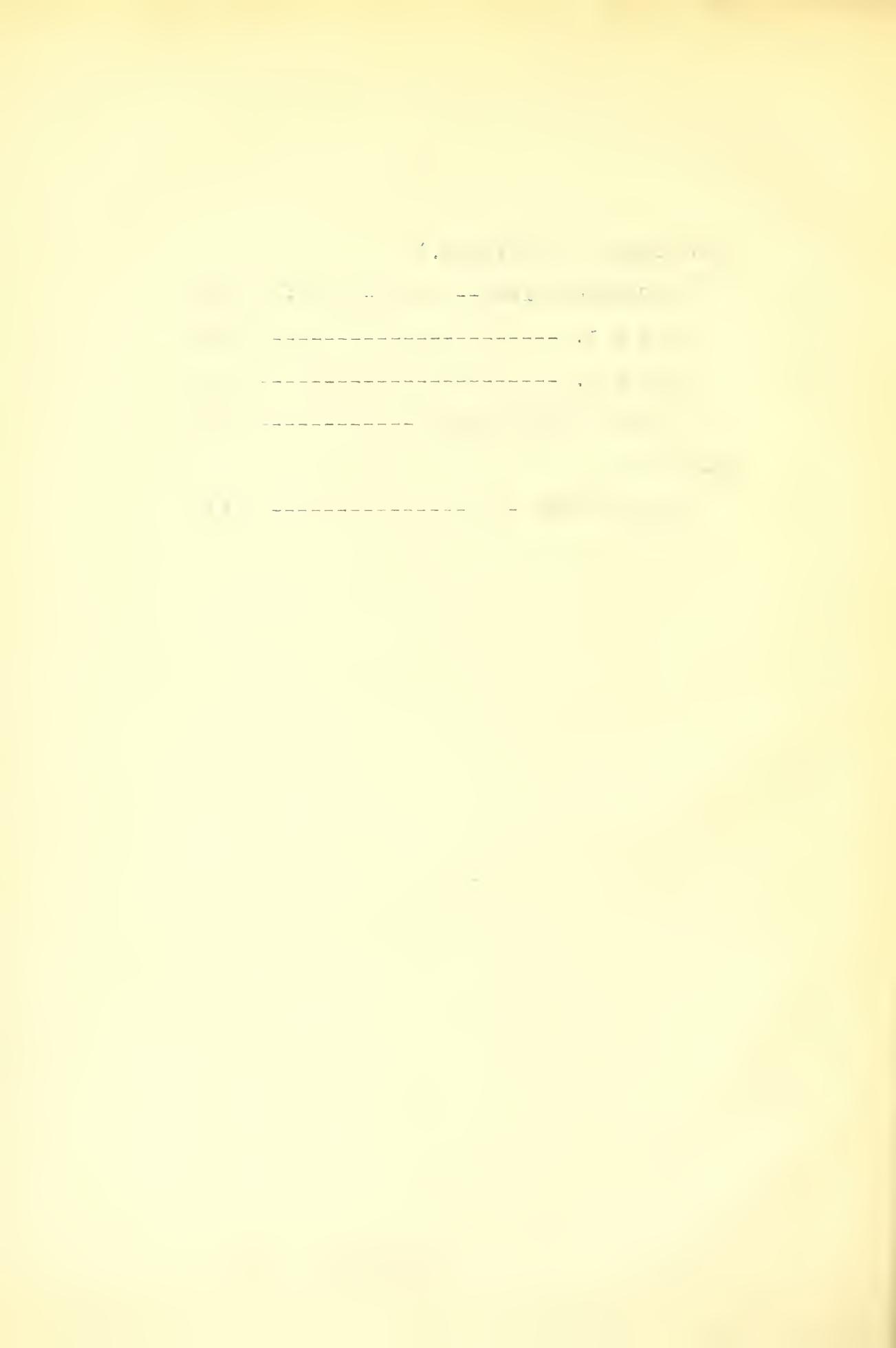
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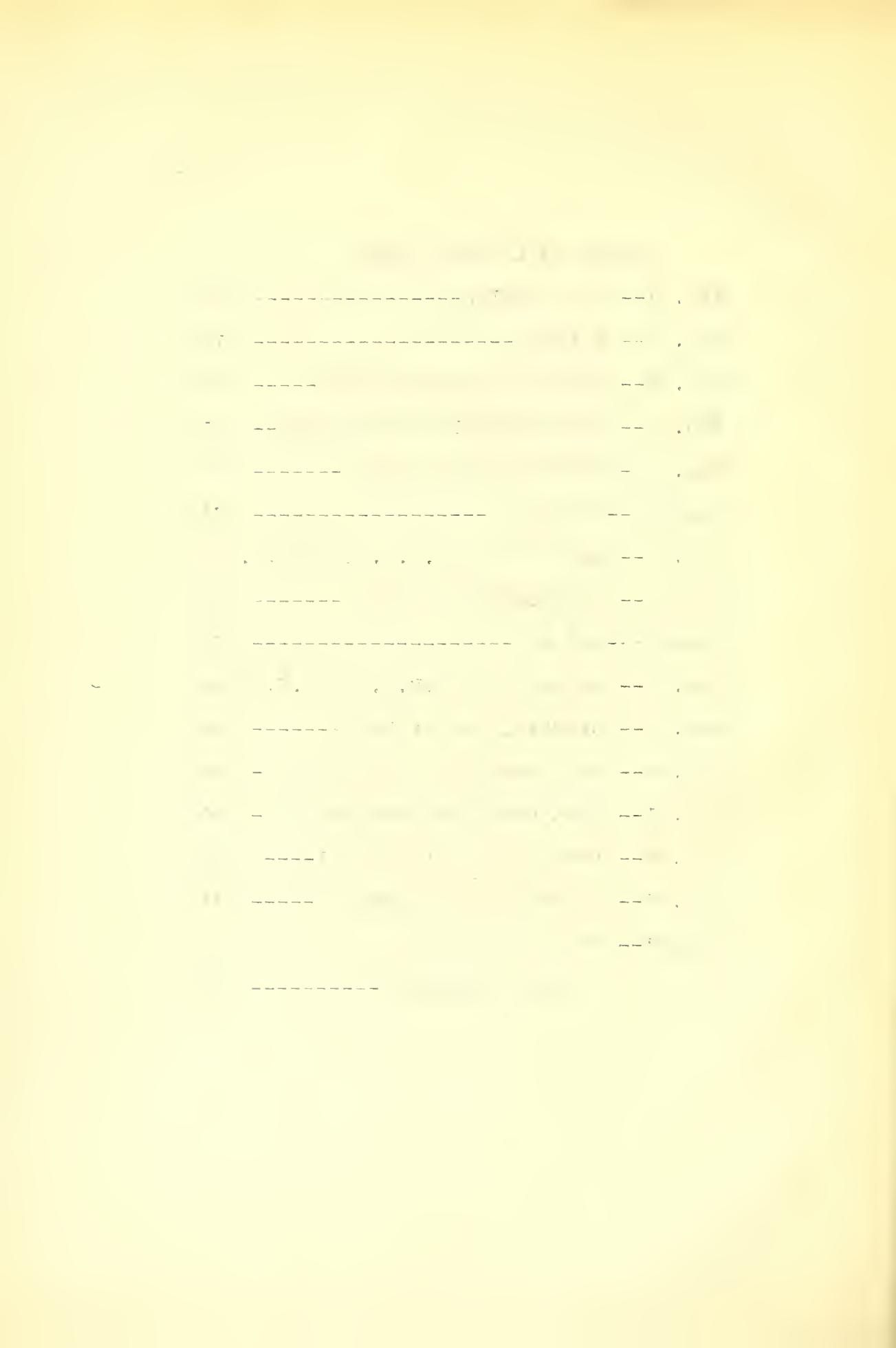
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INTRODUCTION.

At present very little data is available as to the amount of heat wasted or lost in the sensible heat of the exhaust gases of gas engines. This amounts to about 30 or 40 percent of the total available heat, and should be determined more accurately than by rational calculations and temperature entropy diagrams.

At present the method is to obtain the temperature of the exhaust, assuming a specific heat, calculate the weight from the volumetric efficiency, and then calculate the heat lost,

Recognizing the need of more accurate information on this phase of gas engine analysis, it was decided to design and construct an EXHAUST GAS CALORIMETER for High Speed Automobile engines.

— 7 —

and a large number of other species of plants
should be held in check by the same sort of
soil, which is difficult to keep cultivated.
On the 17th December we reached the village
of San Pedro de Atacama, where we were
welcomed with enthusiasm by the inhabitants.
After the usual formalities we were shown into
the house of the priest, who was very kind
and good-natured, and who had been
a student of the author of our guidebook,
and who had given us a copy of his
work, which we had greatly enjoyed.
He told us that he had been educated at
the Seminary of Chuquicamata, and that
he had been a student of the author of
our guidebook, and that he had greatly
enjoyed it.

PERSONNEL.

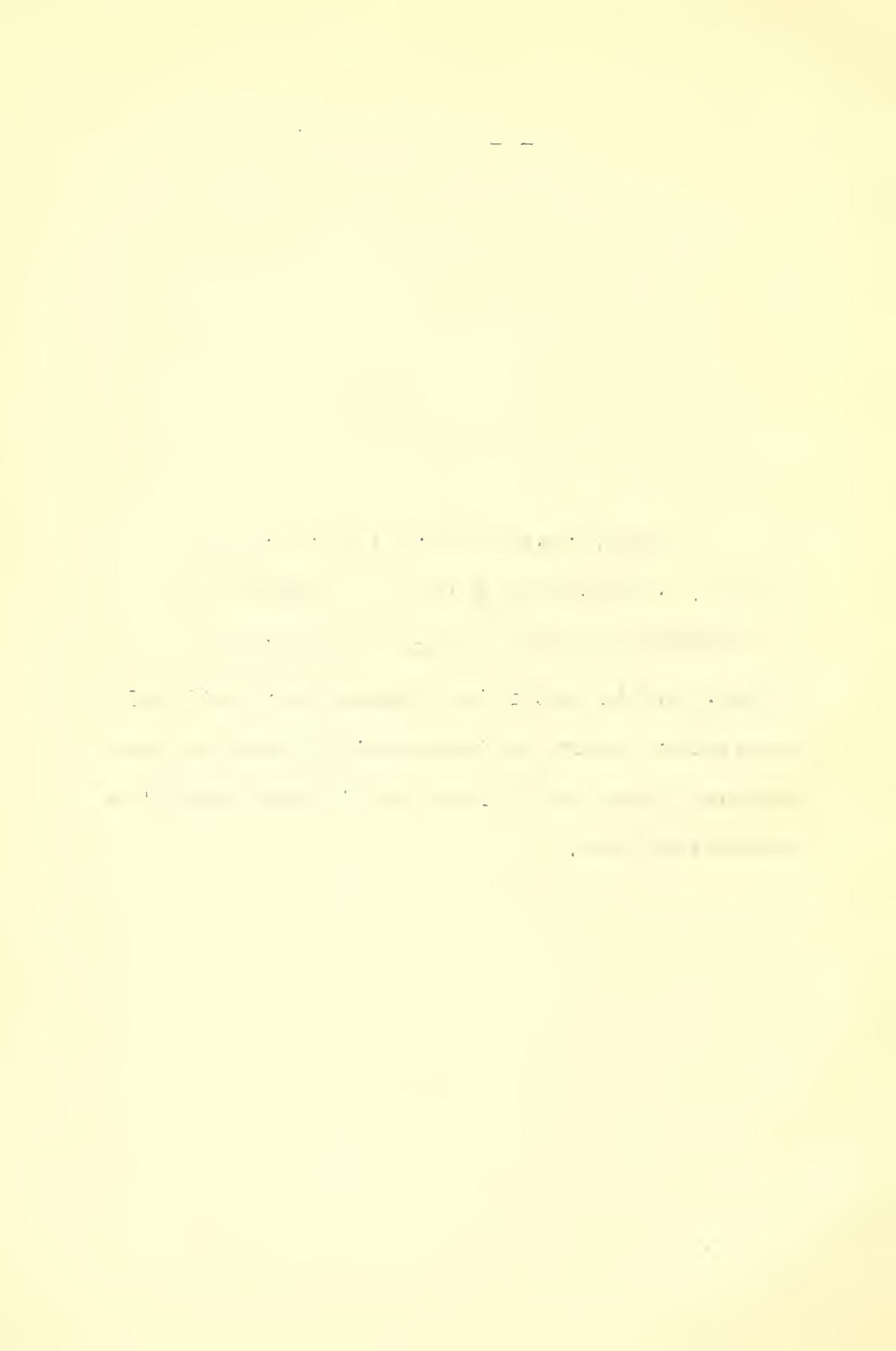
The tests were made under the general direction of G. F. Gebhardt, Professor in charge of the Mechanical Engineering Department, and the personal supervision of Asst. Professor D. Roesch.

Valuable assistance was rendered by Messrs. Bready, Ward and Chipman.

- 3 -

OBJECT.

The object of this thesis is to design, construct and test an EXHAUST GAS CALORIMETER for High Speed Automobile engines, and to determine whether any rational equations governing the sensible heat of the exhaust gases hold true, and if not, what the variations are.



SCOPE OF REPORT.

This thesis is divided into three parts. In the first part is given a complete description of the calorimeter, including its design and method of construction. The second part is devoted exclusively to the description of the engine and its accessory apparatus. The third part, in addition to the results and method of testing, contains a discussion of the results obtained. The fourth part contains our conclusions.

It is believed that the results achieved with the equipment described warrant a more extended research into this phase of gas engine analysis.

PART ONE.

DESCRIPTION OF CALORIMETER,
ITS DESIGN
AND METHOD OF CONSTRUCTION.

THEORY OF CALORIMETER.

The heat to be measured is to be imparted to a stream of water. The weight of water flowing through the calorimeter during the time that a known volume of combustible is consumed in the engine and the resultant temperature of the water, furnish the data necessary to calculate the heat imparted to the water. There is, however, a loss of heat through the calorimeter, the magnitude of which will be neglected in this treatise.

The temperature of the water entering and leaving the calorimeter is measured by means of inlet and outlet thermometers. A large body of water must be provided in the bottom of the calorimeter to thoroughly mix the water before it reaches the outlet thermometer cup, in order that

$\rightarrow \mathbb{F}_q^m$

\vdash

theorem [12, 13] that $\mathcal{O}(\log n)$ is the best possible bound for the number of queries required to identify a target element in a sorted array. This result is often referred to as the "interpolation search" or "log-log search".

Another interesting result is that the average number of comparisons required for an interpolation search is approximately $\log \log n$. This is significantly better than the $\log n$ required for a binary search. For example, for a sorted array of size $n = 10^6$, the average number of comparisons for an interpolation search is approximately 1.44, while for a binary search it is approximately 20.

The interpolation search algorithm can be implemented in several ways. One common approach is to use a recursive divide-and-conquer strategy. Another approach is to use an iterative loop that repeatedly refines the search interval based on the current estimate of the target element's position. Both approaches have their pros and cons, and the choice of implementation depends on the specific requirements of the application.

In conclusion, the interpolation search is a highly efficient search algorithm that can be used to quickly find a target element in a sorted array. Its performance is comparable to that of a binary search, but it requires less memory and is more cache-friendly. It is particularly useful for large datasets where the search interval is known to be sorted. However, it is not suitable for unsorted datasets or for datasets with many duplicates, as it may get stuck in loops or fail to converge.

the thermometer shall indicate the true mean temperature of the effluent water.

The rate of flow of water, and hence its rise in temperature is varied by means of suitable valves in the supply line.

and the first little tickle of a gift
that I can't wait to consider -
but, you know how folks do when you
have a gift you're not quite sure
if you're allowed to open it yet.

DESIGN OF CALORIMETER.

The calorimeter was designed for a six cylinder engine, 450 cu. inches piston displacement and 2000 R.P.M.

$$\frac{450 \times 2000}{2 \times 1728} = 260 \text{ cu. ft. gas per minute}$$

Specific heat of gas = approx. 24

Density = approx..1(avCO₂, N₂)

260 x .24 x .1 = 6.24 BTU per degree difference in temperature.

Assume temperature of exhaust = 900 deg. F.

Assume room temperature = 70 deg. F.

6.24 x (900-70) = 51,800 B.T.U. per min.

Assume 30 degree raise in temperature of water. $\frac{51,800}{30} = 173$ lbs. water per min.

Assuming a velocity of 650. ft. per min.

for the exhaust gases area of passage must

be $\frac{260}{650} = .40$ sq. ft. = 58 sq. in.

The passage ways were made 5" x 12".

the following table.

Table showing the effect of

variations in the value of $\frac{d\theta}{dt}$ on the

value of θ at the time of the first

occurrence of the first maximum of $\frac{d\theta}{dt}$.

Table showing the effect of

variations in the value of $\frac{d\theta}{dt}$ on the

value of θ at the time of the second

maximum of $\frac{d\theta}{dt}$.

It is evident from the first table that

the variation in the value of $\frac{d\theta}{dt}$ has a

considerable influence on the value of θ .

The second table shows that the value of

θ at the time of the first maximum of

$\frac{d\theta}{dt}$ is increased by 20 per cent.

and decreased by 20 per cent. when

the value of $\frac{d\theta}{dt}$ is increased or decreased by

one-half of its original value.

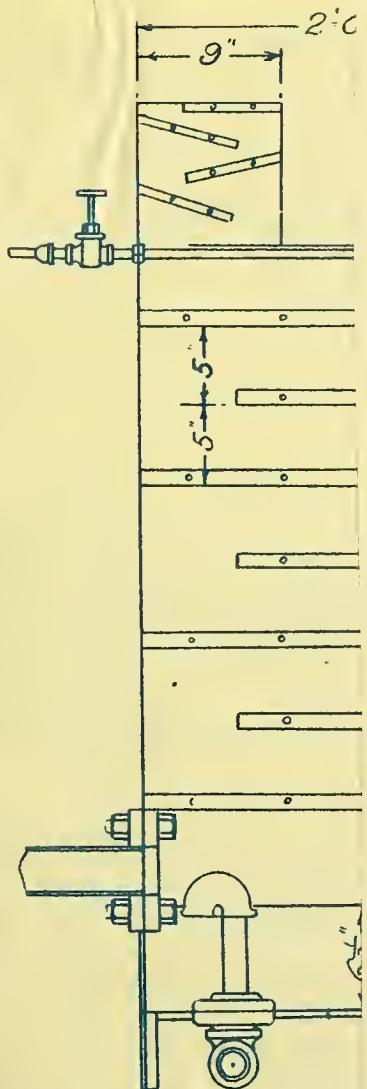
"C" is the original value of $\frac{d\theta}{dt}$.

GENERAL DESCRIPTION OF CALORIMETER.

The calorimeter is of the counter current, rain type, with a series of dry baffles to separate any mechanically entrained water. A sectional view of the calorimeter may be seen on the accompanying sketch, Fig. 1.

There are seven wet baffles and five dry baffles. The latter are located in the tower of the calorimeter.

The water enters in the upper wet pass, and is sprayed by means of three one and one-half inch pipes perforated with one hundred and fifty one-sixteenth holes. The water falls to the top baffles, and is then precipitated over the saw tooth edge in the form of rain. The water falls from baffle to baffle until it reaches the bottom. Here it is subjected to the direct heat of



SECTION

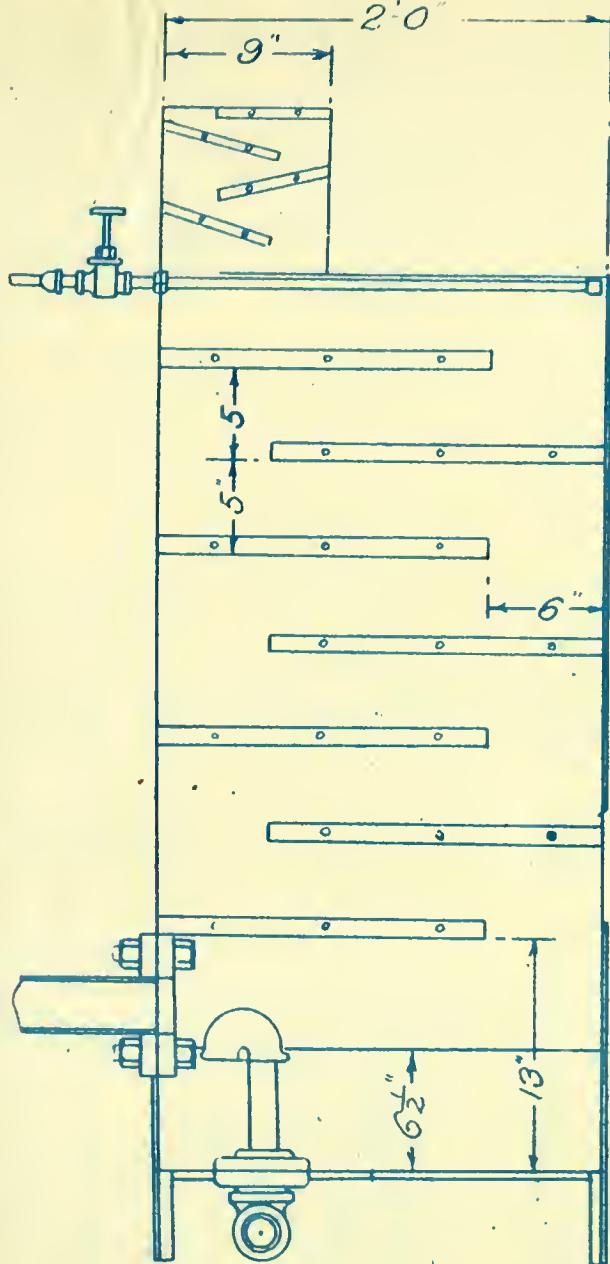
the $\mathcal{O}(n^2)$ time complexity of the naive approach. This is achieved by using a dynamic programming approach where we maintain a table T such that $T[i][j]$ contains the minimum number of operations required to convert the string s_i to t_j . The base case is $T[0][0] = 0$. The recurrence relation is given by:

$$T[i][j] = \min \begin{cases} T[i-1][j-1] + \text{cost}(s_i, t_j) & \text{if } s_i = t_j \\ T[i-1][j] + \text{cost}(s_i, t_j) & \text{if } s_i \neq t_j \\ T[i][j-1] + \text{cost}(s_i, t_j) & \text{if } s_i \neq t_j \end{cases}$$

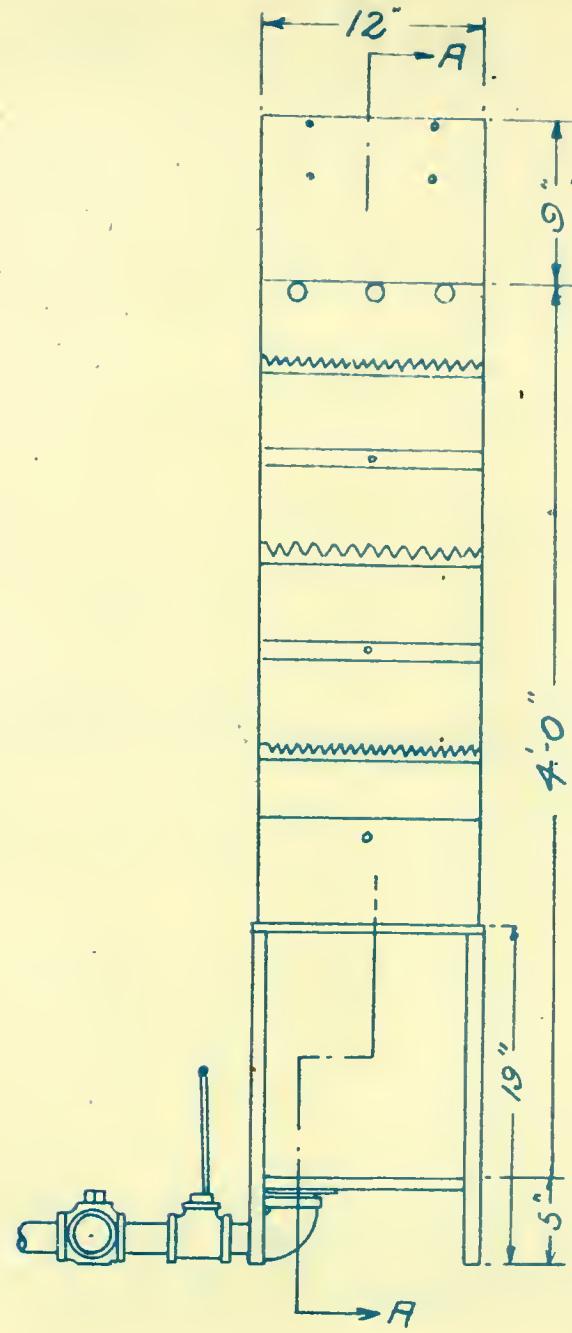
The cost function $\text{cost}(s_i, t_j)$ is defined as follows:

- If $s_i = t_j$, then $\text{cost}(s_i, t_j) = 0$.
- If $s_i \neq t_j$ and $s_i \neq t_{j-1}$, then $\text{cost}(s_i, t_j) = 1$.
- If $s_i \neq t_j$ and $s_i = t_{j-1}$, then $\text{cost}(s_i, t_j) = 2$.

The final answer is $T[n][m]$. The space complexity of this approach is $\mathcal{O}(nm)$.



SECTION "AA"



CALORIMETER
WITH DOOR OFF

Fig. 1.

the incoming gases. A space is provided for a large body of water in the bottom, approximately seventy pounds, so that it may be thoroughly mixed and have a fairly constant temperature. It passes out of the calorimeter through a water seal, and then through a three way cock where it may be directed to either the sewer or a weighing tank.

The amount of water flowing through the calorimeter may be regulated by means of three one-half inch valves in the supply line. The object being to reduce the gases to as near room temperature as the sensitiveness of the calorimeter will permit.

DETAILED DESCRIPTION OF CALORIMETER,

The body of the calorimeter was made of Number 26 galvanized iron, all seams double soldered.

An opening with a removable cover was put in the upper end of the calorimeter to facilitate the proper spacing of the baffles, and also that the action of the saw tooth edge of the baffles could be observed.

The water is led to the calorimeter by means of a one-inch pipe to a one-inch header, to which the spray pipes and regulating valves are attached. The gases are prevented from short circuiting by means of an inch and a quarter return elbow. The return elbow also serves to keep the water level in the calorimeter fairly constant. The elbow is screwed onto a five inch by one and

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四

- 1 -

• $\frac{1}{2} \int_{-\infty}^{\infty} e^{-x^2} dx = \sqrt{\pi}/2$

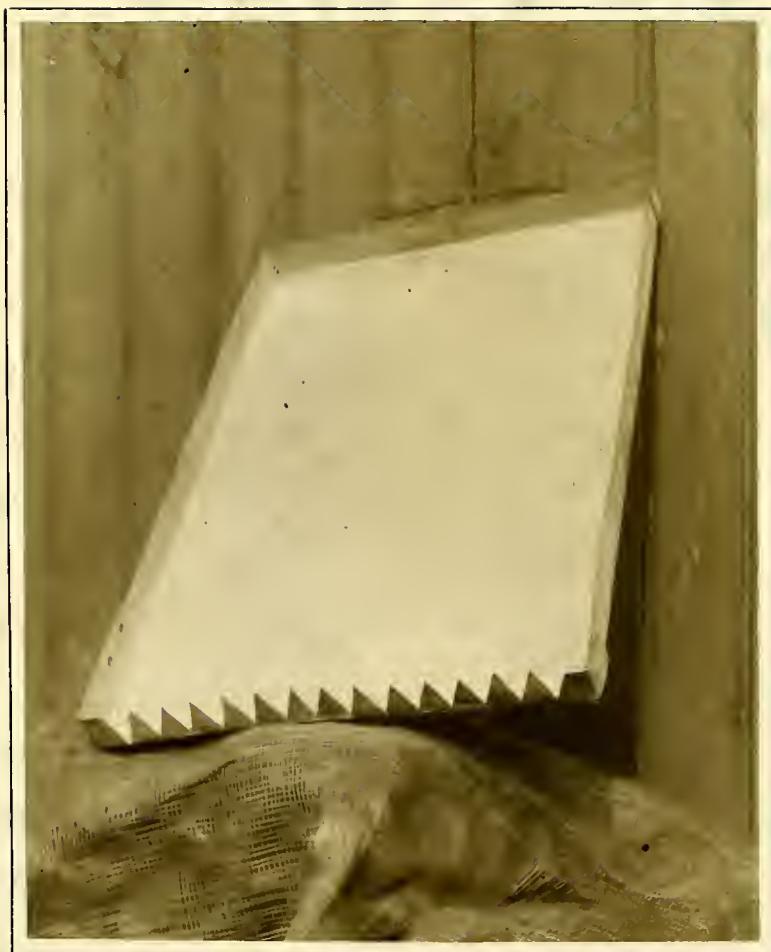
100% 50% 25% 10% 5%

a quarter inch nipple which in turn is connected to flanges bolted to the bottom and made water tight by means of suitable gaskets.

After leaving the calorimeter the water is lead past a thermometer cup to a three way valve, where it may be lead either to a weighing tank or the sewer.

The baffles are 12" x 18" and are placed parallel to the bottom to facilitate in conjunction with the saw tooth edges the rapid cooling of the gases due to the quantity of water held on the baffle. A photo of baffle may be seen on Page 18.

The tower, that is the compartment above the spraying chamber has five wet baffles which act as a separator. These baffles are placed at a slight angle with the horizontal to allow any precipitated moisture to



fall back into the calorimeter.

The gases enter in the lower pass about an inch above the water level through a three inch pipe with suitable flanges and high temperature gaskets. The gases are directed upwards, back and forth and around the baffles, during which time they pass through seven cascades of water, and through the final spraying chamber and thence to the separator. From here they may be allowed to escape to the atmosphere or be run through a meter and measured.

The calorimeter is supported six inches above a table by means of an angle iron frame. This is to allow sufficient room for the exit cooling water pipe.

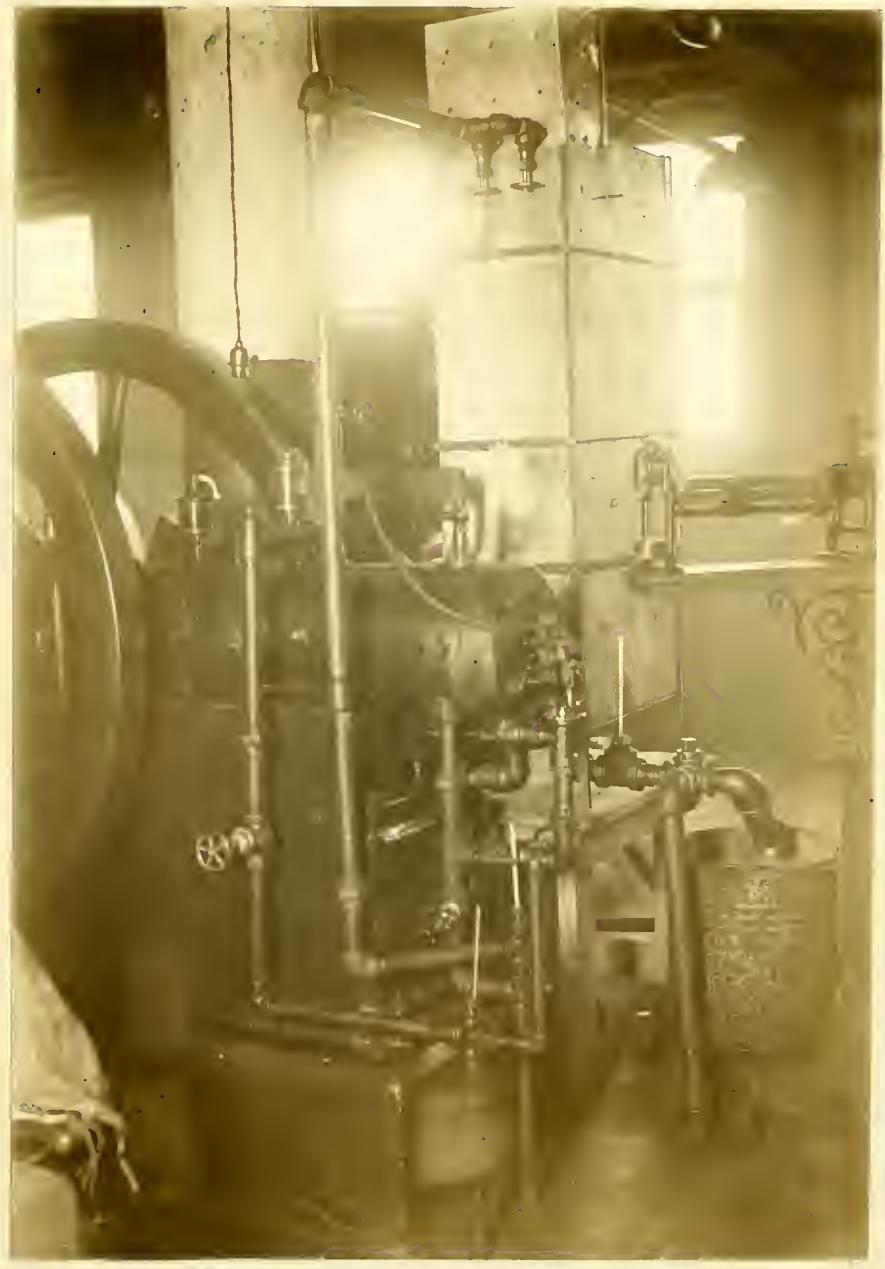
PART TWO.

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DESCRIPTION OF ENGINE
AND
ITS ACCESSORY APPARATUS.

As the automobile engines which were available would necessitate a reconstruction of their exhaust manifolds, it was decided to attach the calorimeter to the Fairbanks-Morse engine, which engine is rated at seven horsepower at 260 R.P.M., the diameter of the cylinder being 6-3/4 inches, with a stroke of 11-15/16 inches.

The valves are of the poppet type. The inlet valve in the head of the cylinder works automatically, while the exhaust valve is operated mechanically by means of a cam which is driven by gears from the main shaft. The speed of the engine is controlled by means of a centrifugal governor which acts on the "hit or miss" principle, that is, when the engine exceeds the normal speed of the governor the mechanism holds the exhaust valve open. The motion of this valve by means of a series of levers, operates a valve in the gas line, which regulates the



supply of fuel to the engine.

The ignition is effected by means of a cam on one of the gear wheels. The motion of the cam is transmitted by means of a shaft to a lever which makes and breaks the circuit in the igniter. The igniter can be set at two positions by means of an ignition lever, the late position makes the spark or point of ignition at 10 degrees late. This position is only used for starting the engine. The other position is 7 degrees early, and is used for the regular running of the engine.

On July 20, 1942, I was sent to the

U.S. Army Air Forces at MacDill Field,

Florida, to receive training in the use of

the 105mm field gun. This included

the use of the gun mount, gun shield, and

ammunition, gun mount, gun shield, and

ACCESSORY APPARATUS.

The load is given the engine by means of a prony brake. This brake is on a water cooled pulley which is keyed to the main shaft, and consists of a number of wooden blocks held together by iron bands. These bands are split at the top and can be adjusted by means of a bolt and nut.

A Crosby Indicator was used to obtain cards from the engine. A 20 pound spring fitted with a stop to prevent the indicator piston from rising too high, was first used to get the pressures in the cylinder during the idle stroke, that is, the suction and the exhaust strokes. This diagram is used for obtaining the back pressure caused by the friction of the gases in the exhaust passages, and in the calorimeter.

the following day. I am still here
and have been for the past week. I have
been working on my thesis and have made
some progress. I am still trying to figure out
the best way to approach the problem. I have
been reading a lot of literature and have found
it very useful. I am also trying to work on my
writing skills. I have been writing a lot of
papers and have found that it helps me to
think more clearly and to express myself better.
I am also trying to work on my communication
skills. I have been working on my presentation
skills and have found that it helps me to
communicate my ideas more effectively. I am
also trying to work on my writing skills. I have
been writing a lot of papers and have found that it
helps me to think more clearly and to express myself better.
I am also trying to work on my communication
skills. I have been working on my presentation
skills and have found that it helps me to
communicate my ideas more effectively.

The calorimeter was connected to the engine by means of a two and one-half inch nipple bushed into a three inch flange of the calorimeter. The one-inch header was connected to the service line by means of a one-inch pipe and suitable fittings.

The other accessory apparatus consisted of weighing tanks and scales for weighing the jacket water, also a tank and box and scale for weighing the calorimeter water; revolution and explosion counters; thermometers for measuring the temperatures of the room, gas inlet and outlet jacket water, and inlet and outlet calorimeter water; prony brake; scale; indicator and manometer for obtaining the pressure of the gas at the meter, and a Junker calorimeter with its accessory apparatus for determining the heat content of the fuel gas.

PART THREE.

RESULTS AND DISCUSSION.

INTRODUCTION.

The general condition of the engine would not permit runs of sufficient duration to be made; so that the data embodied in this report is not to be relied upon for any degree of exactness.

As the conditions imposed on us during the tests, compelled us to take only the absolutely essential data, it was deemed advisable to take but one reading on the Junkers Gas calorimeter.

Throughout the runs the usual data for any engine tests were taken, and in addition the various calorimeter readings.

While it would have been advisable to make an analysis of the exhaust gas by means of an Orsat apparatus in order to determine the character and amount of unburned gases, as previously stated, conditions prohibited us from making this analysis.

the first time in the history of the world, the
whole of the human race has been gathered
together in one place, and that is the
present meeting of the World's Fair.
The people of the United States have
done their best to make this fair a success,
and they have succeeded. The people of
the United States have done their best to
make this fair a success, and they have
succeeded. The people of the United States
have done their best to make this fair a success,
and they have succeeded. The people of the
United States have done their best to make
this fair a success, and they have succeeded.

PRELIMINARY RUN.

After the apparatus had been assembled a preliminary run was made. During the course of this run several minor water leaks developed. A breathing action caused by the hit or miss type of governing was observed in the lower wet pass. It was decided that this was too pronounced for safety; accordingly three lateral horizontal stays and one longitudinal stay, all made of one-quarter inch soft steel rods, were added.

The cover over the observation opening bulged considerably, due to the back pressure and lack of sufficient strength. It was decided that the quickest and most efficient way to remedy this was to put boards over the ends and hold them together by means of tie rods. After making these changes a complete test was made, varying the load from zero to a maximum. Consider-

able trouble was encountered in procuring the desired temperatures of the exhaust gas and water.

The calorimeter which was designed for a six cylinder engine five times as large as the Farbanks-Morse Engine was found to be too large. When the amount of water used was cut down so that the exhaust gases would issue at room temperature, it would steam in the lower wet pass. When enough water was admitted so that moderate temperatures were secured in the lower pass, the issuing exhaust gas was too cool. It was also found that the calorimeter had a considerable lag, that is, any adjustment of the regulating valves brought instantaneous decrease in the temperature of the exhaust gas, but did not change the issuing water until several minutes later.

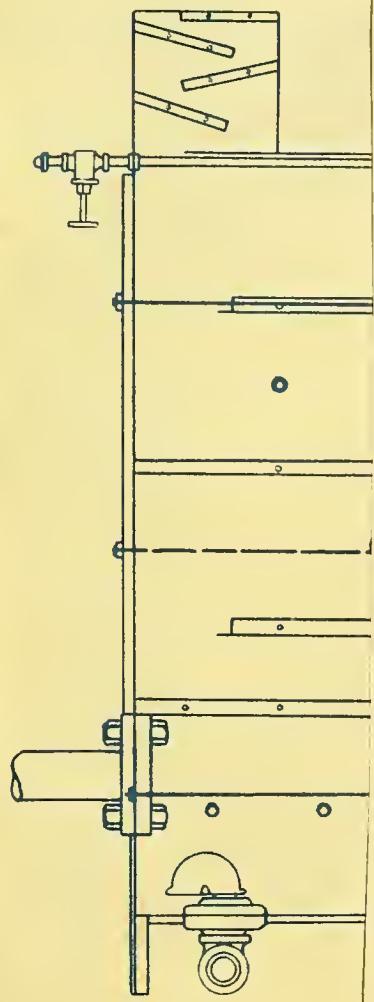
RECONSTRUCTION OF CALORIMETER.

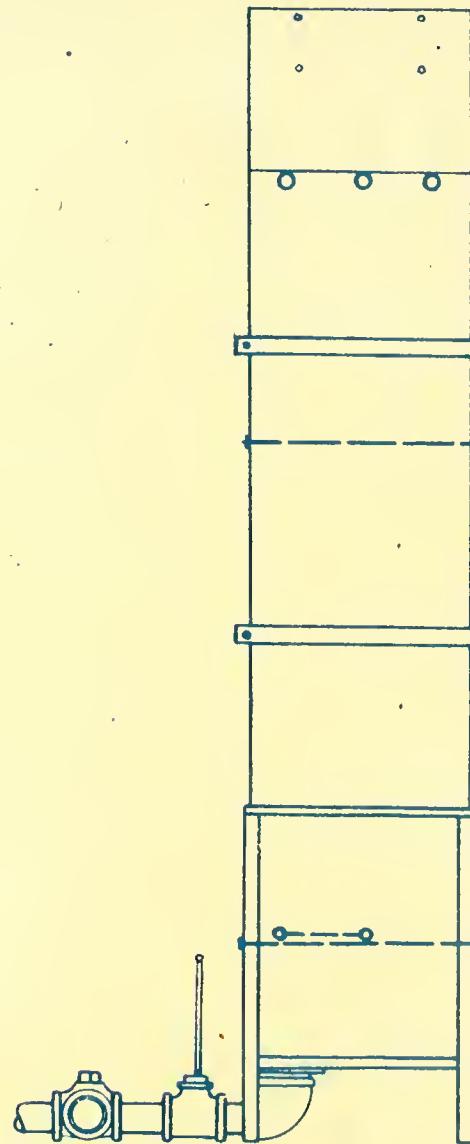
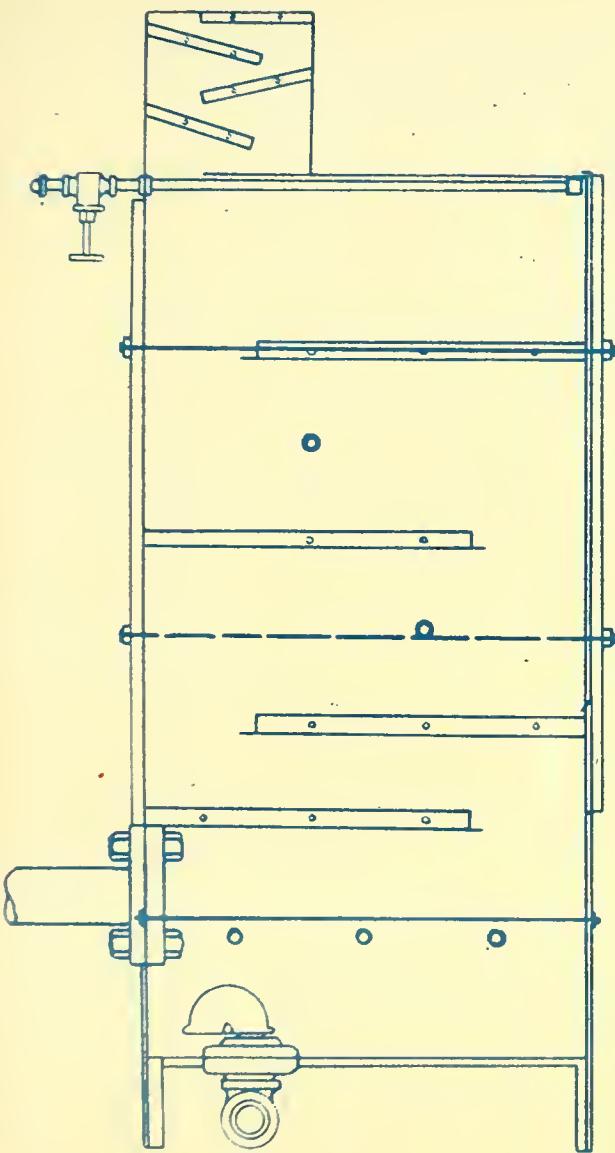
It was, therefore, decided that, in order to obtain the desired results from this engine, it would be necessary to cut down the amount of water contained in the calorimeter, and also by-pass the spraying chamber, and cut out several passes. A drawing of the reconstructed calorimeter is shown on the preceding page.

To facilitate more instantaneous operation the quantity of water was cut down in the lower wet pass by shortening the nipple on the water seal, and by bending over the saw tooth edges so that a minimum amount of water was stored on the baffles.

A photograph of the reconstructed baffle is shown on page 32.

After the above-mentioned changes had been made, another complete run was made.





RECONSTRUCTED
VIEW OF
CALORIMETER

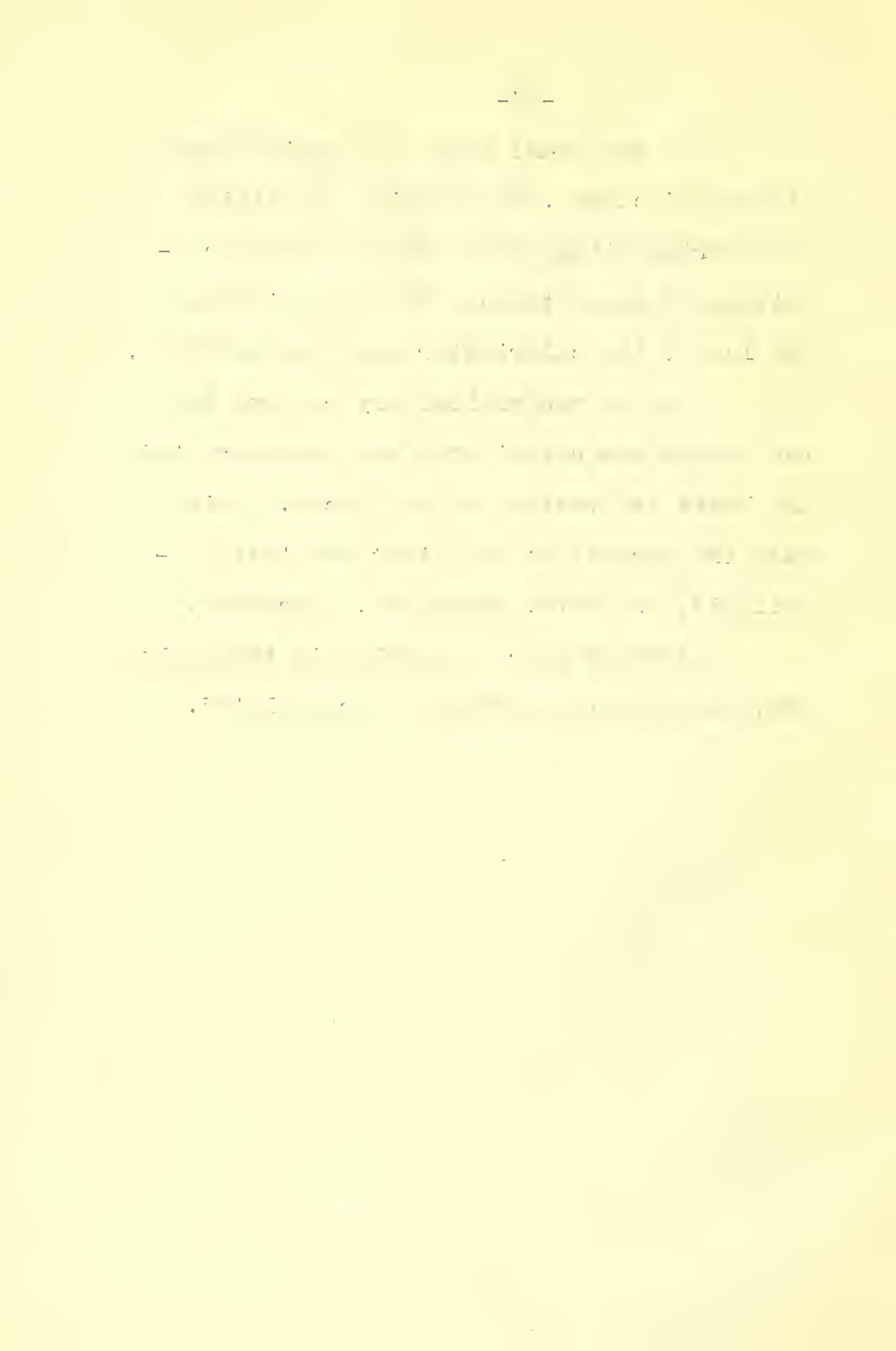
Fig 4



It was found that the previous mentioned objections, the bulging, breathing and refrigerating effect and the short circuiting of gases through the exit pipe and the lag of the calorimeter had been remedied.

During the preliminary run and the run before the calorimeter was reconstructed, the brake arm rested on two places. This made the results of the first two tests unreliable, and were, therefore, discarded.

Another notch was filed in the brake arm, and the brake constant recalculated.



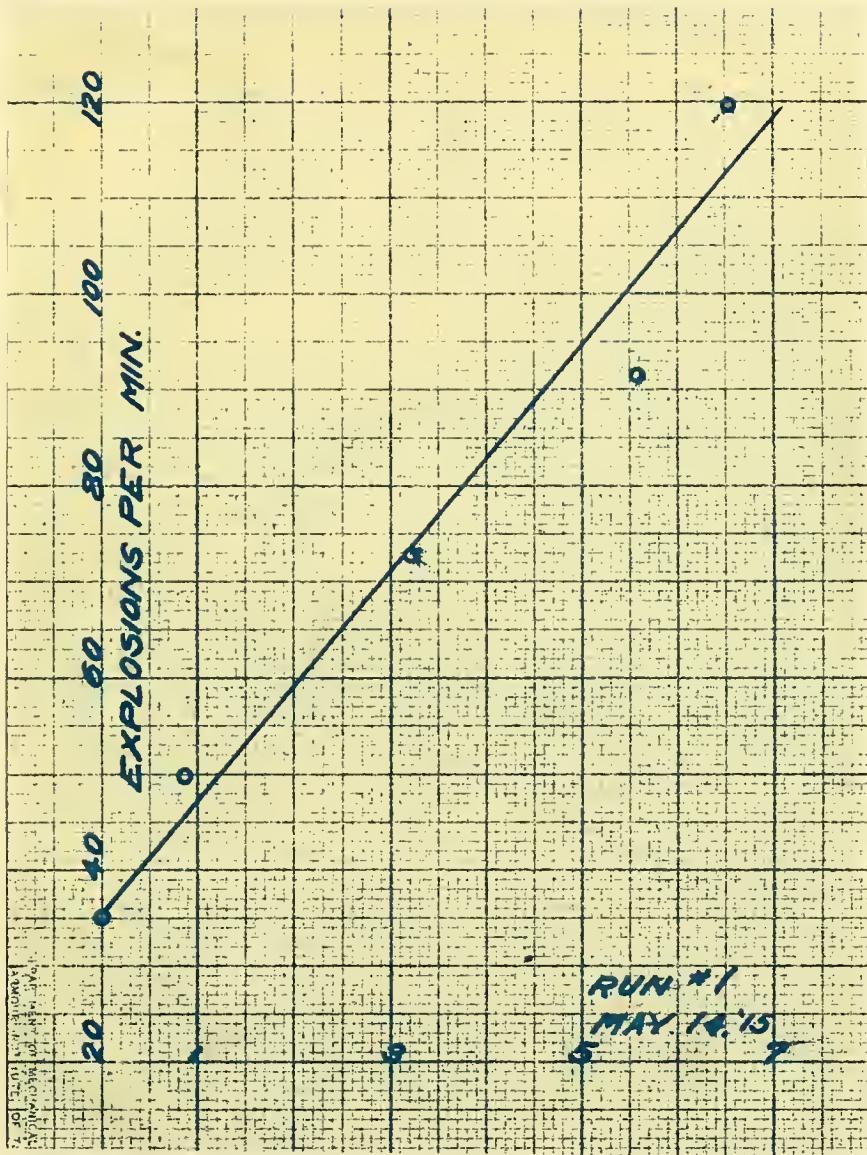
TEST OF

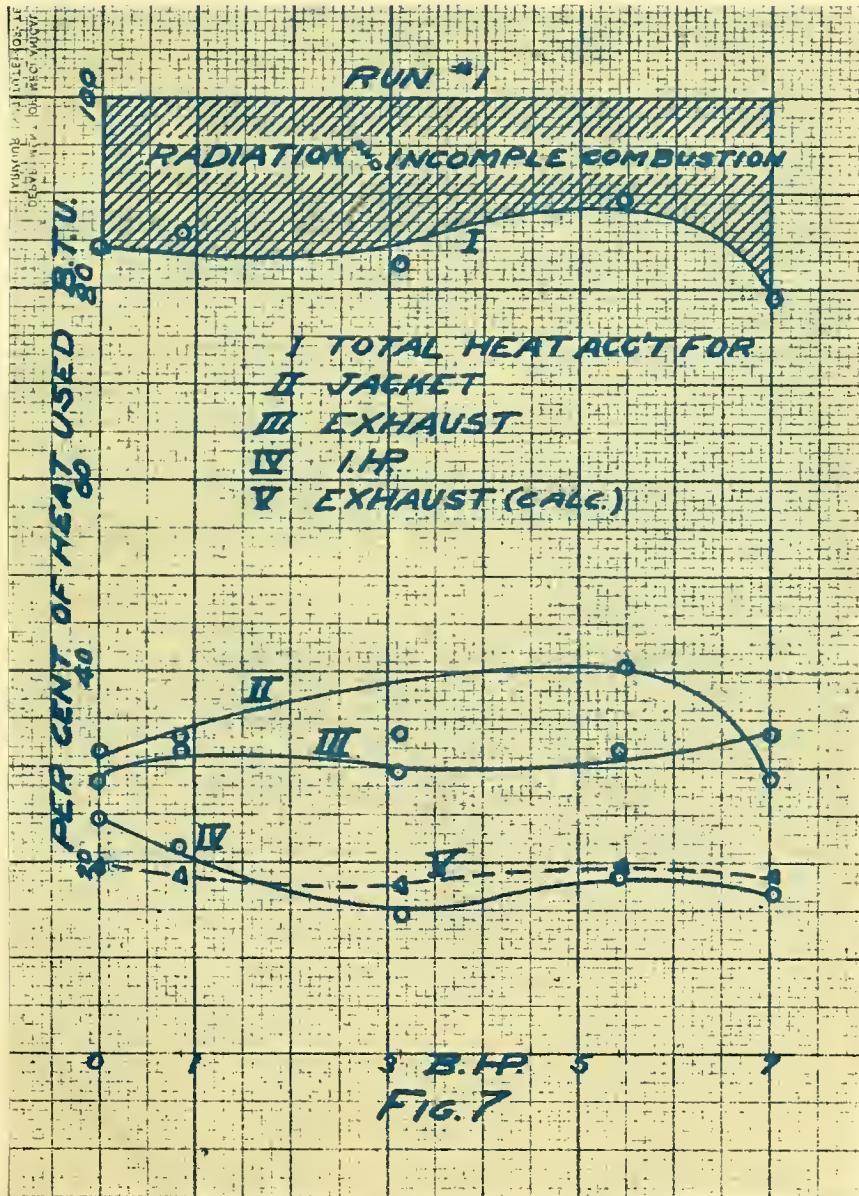
DURATION OF RUN	
NET LOAD ON BR.	
GAS CONSUMED	
CALORIFIC VALUE	
JACKET WATER F	
GAS PER HR	
GAS AT METER	
BAROMETER	
CALORIMETER WAT.	
SUPPLY WATE.	
JACKET WATE,	
GAS AT METER	
ROOM	
EXHAUST	
CALORIMETER WAT.	
R. P. M.	
EXPLOSIONS PER 1	
M.E.R	
I.H.P.	
B.H.P	
MECH EFF.	
HEAT SUPPLIED F	
HEAT IN JACKET	
HEAT IN EXHAUST	
HEAT EQUIVALENT	
HEAT IN JACKET	
HEAT IN EXHAUST	
HEAT PER I.H.P.	
HEAT IN EXHAUST (C)	

TEST OF FAIRBANKS MORSE GAS ENGINE
RUN #1

MAY 14, 1915.
J.L. MAYER IN CHARGE

DURATION OF RUN	MIN	10	15	8	12	5
NET LOAD ON BRAKE	LBS.	0	7.7	27.7	47.7	67.7
GAS CONSUMED	CUFT. STD.	9.27	20.95	19.3	28.55	16.7
CALORIFIC VALUE OF GAS TOTAL		705	705	705	705	705
JACKET WATER PER HR	LBS	4152	900	1012.5	765	900.
GAS PER HR	CU. FT. STD.	55.67	83.8	144.75	142.75	200.4
GAS AT METER	IN. HG.	29.57	29.57	29.57	29.57	29.57
BAROMETER	IN. HG	29.43	29.43	29.43	29.43	29.43
CALORIMETER WATER OUTLET	°F	84	84.75	100.5	106.5	90.3
SUPPLY WATER INLET	°F.	53	53	53	53	53.
JACKET WATER OUTLET	°F.	56	74.2	86.5	106.	98.3
GAS AT METER	°F.	62	62	62	62	62.
ROOM	°F.	60	59	58	58.	59.5
EXHAUST	°F.	60	61	64	62.5	60.0
CALORIMETER WATER PER HR. LBS		345.0	604.	641.25	600.0	1270.
R.P.M.		268.5	265	267.	267.	244.
EXPLOSIONS PER MIN.		35.5	50	73.5	90.5	120
M.E.R	LBS	83.9	75.9	72.5	73.5	70.1
I.H.P		3.85	4.91	5.95	7.20	7.18
B.H.P		0	.876	3.12	5.43	7.03
MECH EFF.	%	0	17.8	52.3	75.3	76.5
HEAT SUPPLIED PER HR.	B.T.U	39200	59100	102,000	100,700	141000
HEAT IN JACKET	B.T.U.	12,450	19,100	35100	40,500	40800
HEAT IN EXHAUST	B.T.U.	10,700	18,750	30,500	32,100	47,000
HEAT EQUIVALENT OF I.H.P	B.T.U.	9,550	12,500	15150	18,350	23,400
HEAT IN JACKET	%	31.8	32.15	34.4	40.1	29.0
HEAT IN EXHAUST	%	28.3	31.7	29.8	31.8	33.3
HEAT PER I.H.P	%	24.4	21.1	14.8	18.2	16.6
HEAT IN EXHAUST (CALCULATED)	%	19.7	18.3	17.15	19.7	18.55





RUN NUMBER 1.

During this run the mixing valve was inadvertently changed so that this data, when plotted, as shown in Figure 7, Page 37, did not give uniform results.

There was considerable leakage of exhaust gas and water in the top of the spraying chamber, due to back pressure. As the gas had already given up its heat to the water, and as the water at this point had received very little heat from the gas, it was decided to neglect this entirely.

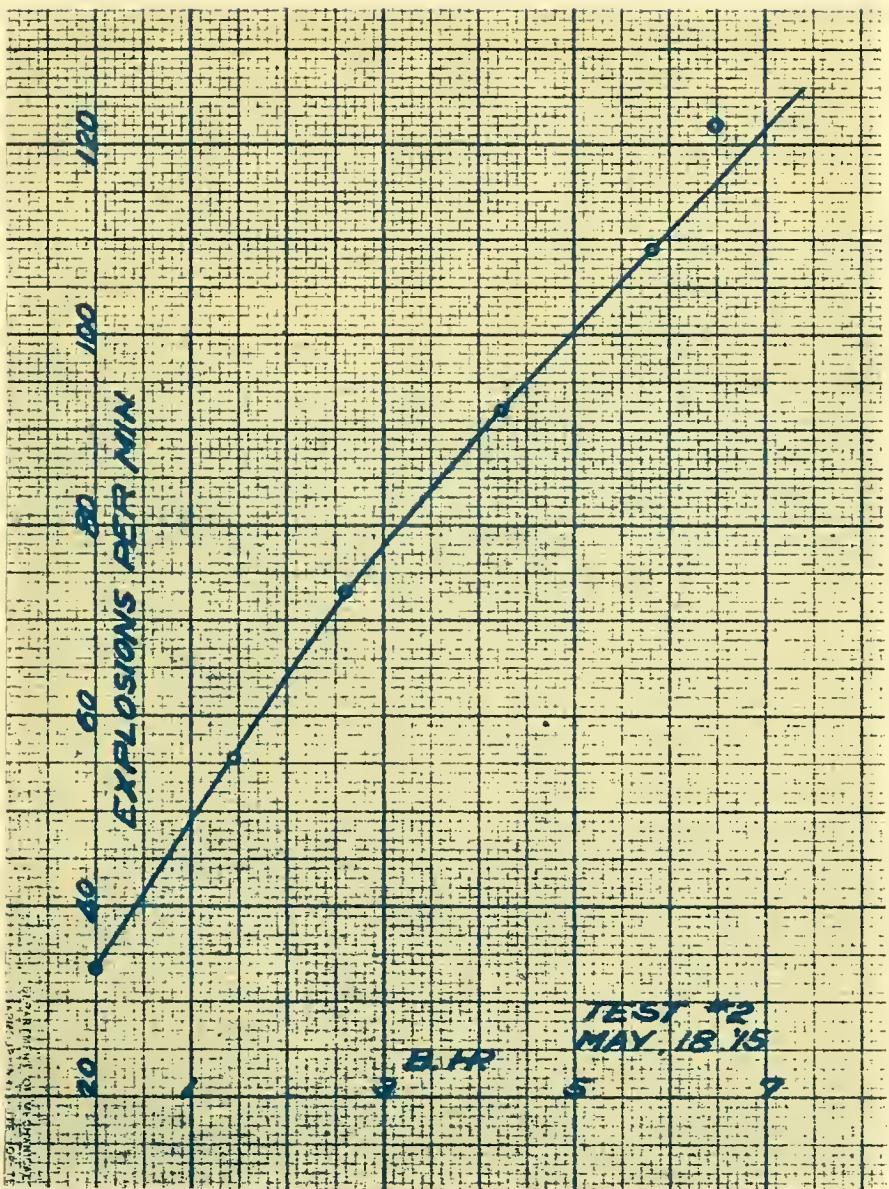
T_l

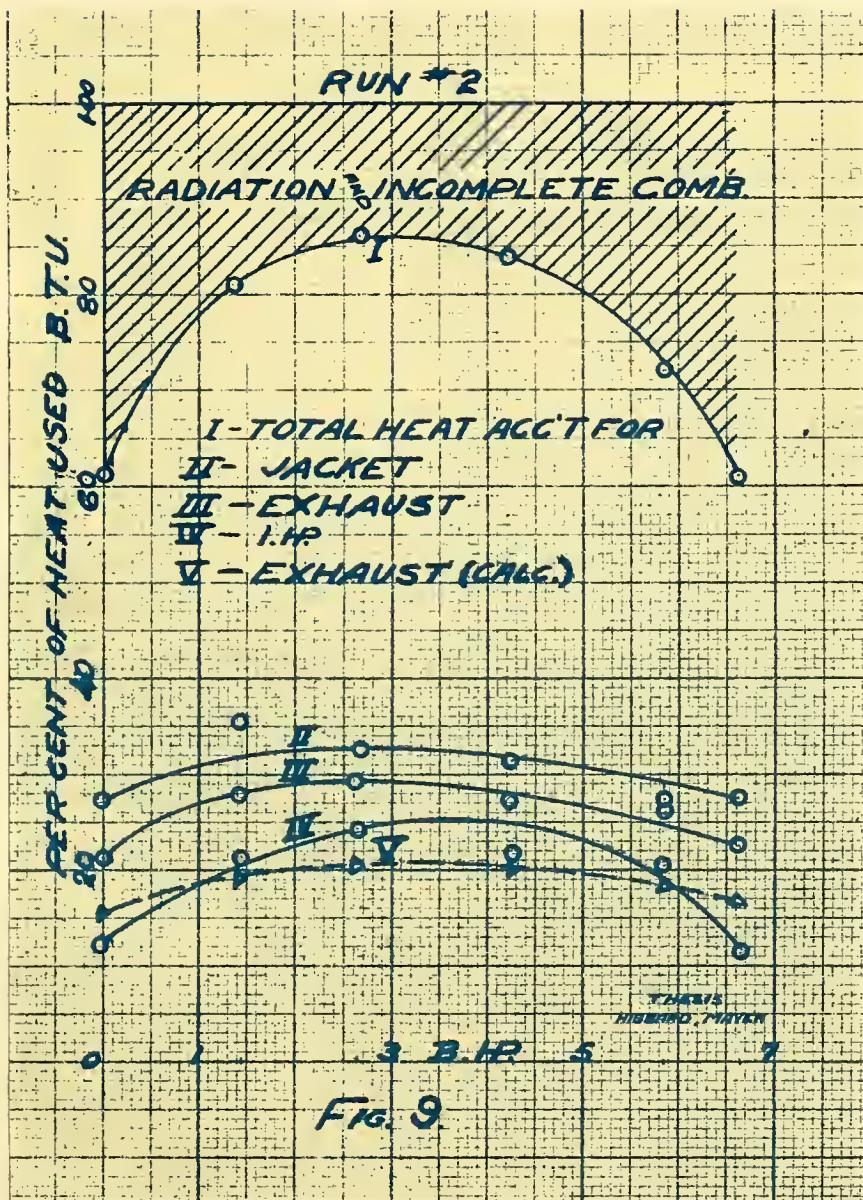
DURATION OF NET LOAD ON	
GAS CONSUME	
CALORIFIC VA	
JACKET WATE	
GAS PER HR.	
GAS AT MET	
BAROMETER	
CALORIMER WAT	
SUPPLY INLET	
JACKET OUTLE	
GAS AT METER	
ROOM TEMP.	
EXHAUST	
CALOR. WATE	
R.P.M.	
EXP. P.M.	
M.E.P.	
ACTUAL I.H.P.	
ACTUAL B.I.P.	
MECH. EFF	
B.T.U. SUPPLI	
HEAT IN JAC	
HEAT IN EXH	
" EQUIVA	
" "	
" IN EXH	
" " JACK	
" " EXHA	

TEST OF FAIRBANKS MORSE GAS ENGINE
RUN #2.

MAY 18 1915—
J.L. MAVER LHM BOARD

DURATION OF RUN	MIN.	10	10	10	10	10	10	5
NET LOAD ON BRAKE	LBS.	0	12.7	22.7	37.7	52.7	62.7	
GAS CONSUMED	CU. FT. (STD)	10.6	13.7	17.5	22.0	28.6	18.7	
CALORIFIC VALUE OF GAS	B.t.u	705	705	705	705	705	705	
JACKET WATER PER HR	LBS.	807	705	540	564	704	895	
GAS PER HR.	CU. FT. (STD)	64	82.5	105	132	170	224.3	
GAS AT METER	IN. HG.	29.98	29.98	29.98	29.98	29.98	29.98	
BAROMETER	IN. HG.	29.65	29.65	29.65	29.65	29.65	29.65	
CALORIMER WATER OUTLET	°F.	76	75	80	99	88.5	82.5	
SUPPLY INLET	°F.	53	53	53	53	53	53	
JACKET OUTLET	°F.	69	81.5	97	104.7	99.7	102	
GAS AT METER	°F.	58	59	62	65	68	60	
ROOM TEMP.	°F.	56	56	58.5	58	60	57.5	
EXHAUST	°F.	57	56.6	58.5	62	61	60	
CALOR. WATER PER HR.	LBS.	395.4	492.0	817.5	549.0	933.0	1194.0	
R.P.M.		265.5	267.0	270.0	264.5	260.0	244.0	
EXP.R.P.M.		33.5	55.5	73.0	91.6	105.5	122.	
M.E.P.	LBS.	71.3	68	67.5	6.66	70.4	65.2	
ACTUAL I.H.P.		3.1	4.88	7.12	7.9	9.6	10.6	
ACTUAL B.H.P.		0	1.45	2.61	4.25	5.85	6.65	
MECH. EFF	%	0	28.6	36.6	53.8	60.8	62.7	
B.T.U. SUPPLIED PER HR	BT.U.	45200	58200	74000	93000	120,000	158000	
HEAT IN JACKET	BT.U.	12,900	20,500	23,800	29,200	32,900	43,800	
HEAT IN EXHAUST	BT.U.	9,700	11,300	22,100	25,300	32,100	35,160	
" EQUIVALENT I.H.P.	BT.U.	7,890	12,410	18,120	19,850	24,420	25,900	
" " "	%	17.4	21.3	24.5	21.3	20.3	16.4	
" IN EXHAUST	%	21.2	19.4	29.9	27	26.7	22.2	
" " JACKET	%	27.5	35.2	32.6	31.4	27.4	27.7	
" " EXHAUST (CALCULATED)	%	15.5	19.9	20.6	20.65	18.5	16.3	





RUN NUMBER 2,

During this run the mixing valve was set in one position, and care was taken that its adjustment was not changed.

When the engine was run at its rated power considerable trouble was experienced in making the engine hold its load. Its operation was accompanied by occasional backfiring. However, as the greater part of the run had been made it was decided to continue the run with the same mixing valve adjustment.

The gas consumption was also higher than on the previous run.

No trouble was experienced in keeping the calorimeter temperatures at the desired points.

During this and the previous run light spring cards were taken, in order to obtain the back pressure caused by the cal-

APPENDIX C

The many applications of the concept
of "natural" and "cultural" selection in
the study of human evolution and
the development of human civilization
are best illustrated by examples from
the field of human cultural evolution.
The first example concerns the evolution
of language. The concept of "natural"
language can be easily understood if we
consider the evolution of language in
terms of the concept of "cultural
selection". The main idea behind
this concept is that language is
not a biological product of natural
selection, but rather a cultural
product of "cultural selection".
The concept of "cultural selection"
is based on the observation that
languages change over time, and
that this change is not random,
but rather follows certain
regular patterns. These patterns
can be described as follows:
1. Languages tend to change
over time, and this change is
not random, but rather follows
certain regular patterns.

orimeter. Several of these cards are shown on Page 45. The back pressure was about .8 of a pound at rated load.

The cards taken at full load, with a 240 pound spring, shown on Page 46, show clearly the irregularity of the action of the mixing valve. These cards were taken from cut-out to cut-out. The M.E.P. decreased with the increase in load.

The heat balance was plotted for both runs, in terms of the percent of total heat.

The exhaust gas loss was then calculated rationally, and also plotted.

The method of calculating the various losses is clearly shown on the preceding pages.

poorly defined and the last one is
the most difficult to define. The first
is the "natural" or "normal" state of
the body, the second is the "pathological"
state, and the third is the "abnormal"
state. The "natural" state is the state
of the body when it is healthy and
there is no disease. The "pathological"
state is the state of the body when
there is a disease. The "abnormal"
state is the state of the body when
there is a disease, but the disease
is not present in the body.

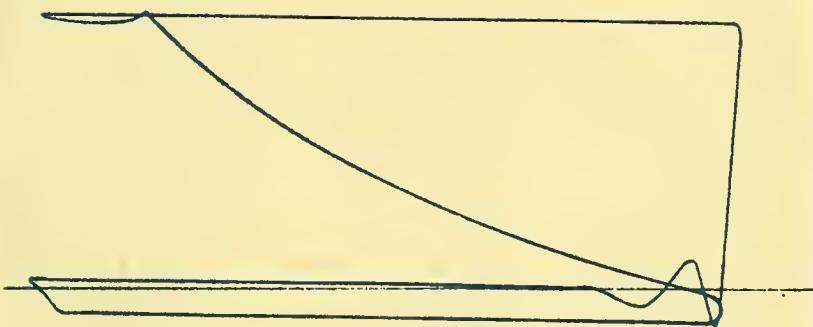


FIG. 10. BACK PRESSURE CARD
RUN #1 FULL LOAD.

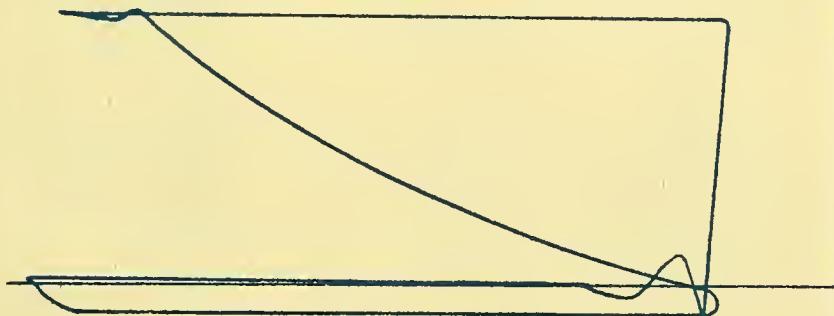


FIG. 11. BACK PRESSURE CARD
RUN #2 FULL LOAD.

In using the rational equations previously mentioned the volume of mixture was found by multiplying the piston displacement by the number of explosions and the temperature of the exhaust. The heat lost in the exhaust per hour is found by multiplying the weight of the exhaust gases per hour, by the specific heat, and by the temperature change. This can be expressed by the following formulae: $B.T.U./hr. = \frac{WSQ(T - T')}{1 \text{ cu.ft.}}$

Where W = weight of mixture per hr.

Q = no. of cu. ft. of mix./hr.

S = Specific heat of mixture

T = temp. of Exhaust gases

T' = temp of room.



FIG. 12. INDICATOR CARDS FULL LOAD. RUN #1. M.E.P. 94.5 LBS.



FIG. 13.
RUN. #2. FULL LOAD CARDS.
M.E.P. 68.5 LBS.

CALCULATED HEAT IN EXHAUST GAS

$$\begin{aligned} \text{Total displ} &= \text{vol piston displ} \times \text{EPM} \times 60 \\ &= 6.75 \times 6.75 \times \frac{3.14}{4} \times 11.94 \times 60 \times 35.5 \\ &= 1805 \text{ cu ft per hour.} \end{aligned}$$

Gas per hour = from log.

$$\begin{aligned} \text{Air per hour} &= \text{Total displ} - \text{gas per hour} \\ &= 1805 - 224.3 = 1580.7 \end{aligned}$$

$$\begin{aligned} \text{Air / hr. lbs} &= \frac{\text{Air / hr cu ft}}{14.2} \\ &= \frac{1580.7}{14.2} = 11.3 \text{ lbs /hr.} \end{aligned}$$

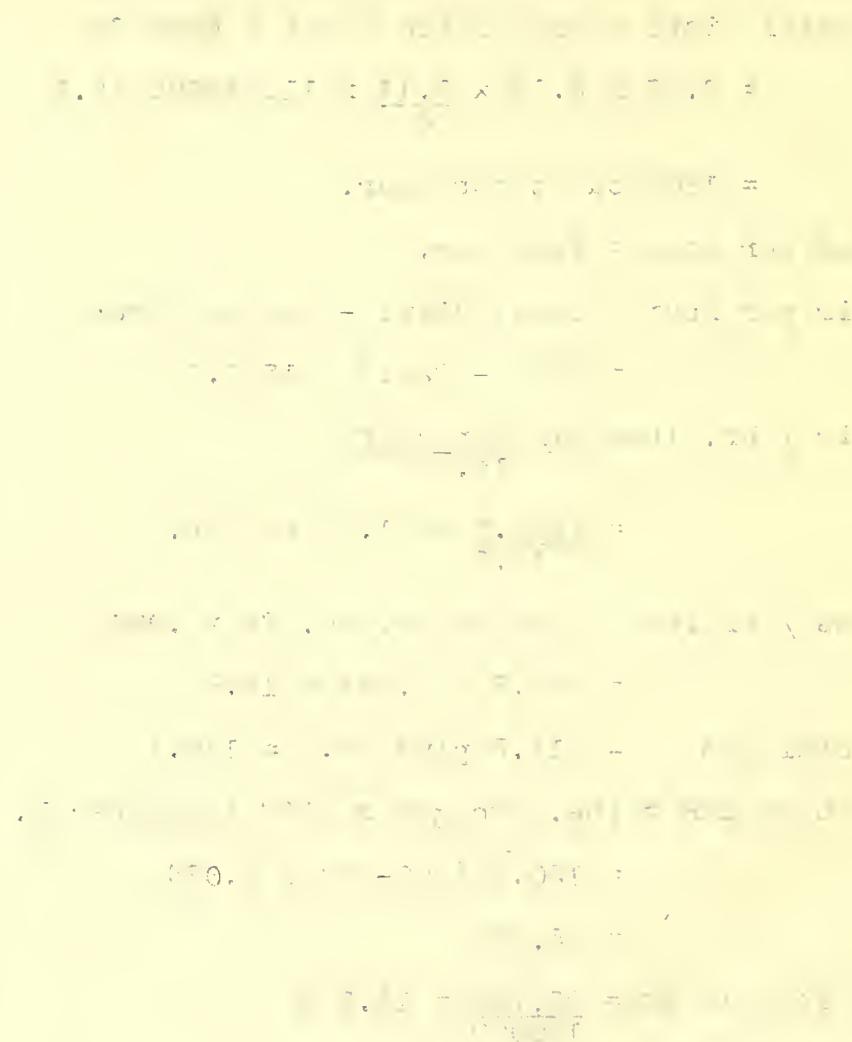
$$\begin{aligned} \text{Gas / hr.lbs} &= \text{gas per hr. cu. ft} \times .084 \\ &= 224.3 \times 0.084 = 18.8 \end{aligned}$$

$$\text{Total lbs} = 111.3 \text{ plus } 18.8 = 130.1$$

$$\begin{aligned} \text{BTU in EXH} &= \text{lbs. exh gas} \times \text{diff temp} \times \text{Spec H.} \\ &= 130.1 \times (900-60) \times 0.084 \\ &= 25,700 \end{aligned}$$

$$\% \text{ lost in Exh} = \frac{25,700}{158000} = 16.3 \%$$

二、(A) 水素の吸収による電位変化



SAMPLE CALCULATIONS

$$\text{CU.FT.GAS/HR.} = \frac{\text{GAS CON.} \times \text{ABS TEMP} \times \text{ST. PR.}}{\text{ST.ABS.TEMP} \times \text{PR. AT METER}}$$

$$\frac{18.7 \times 520 \times 30 \times 12}{522 \times 29.98} = 224.3 \text{ cu.ft/ hr.}$$

Cu ft / hr x heat value gas = BTU supplied/hr.

$$224.3 \times 705 = 158,000. \text{ BTU supplied / hr.}$$

$$\text{I.H.P.} \times 2546 = \text{heat equiv of IHP.}$$

$$10.6 \times 2546 = \text{heat equiv of IHPL}$$

$$\frac{\text{Heat equiv}}{\text{Heat supplied}} = \% \text{ heat in IHP.}$$

$$\frac{25,900}{158,000} = \% \text{ heat in IHP.}$$

$$\text{Diff. in temp.} \times \text{water / hr.} = \text{BTU in Exhaust}$$

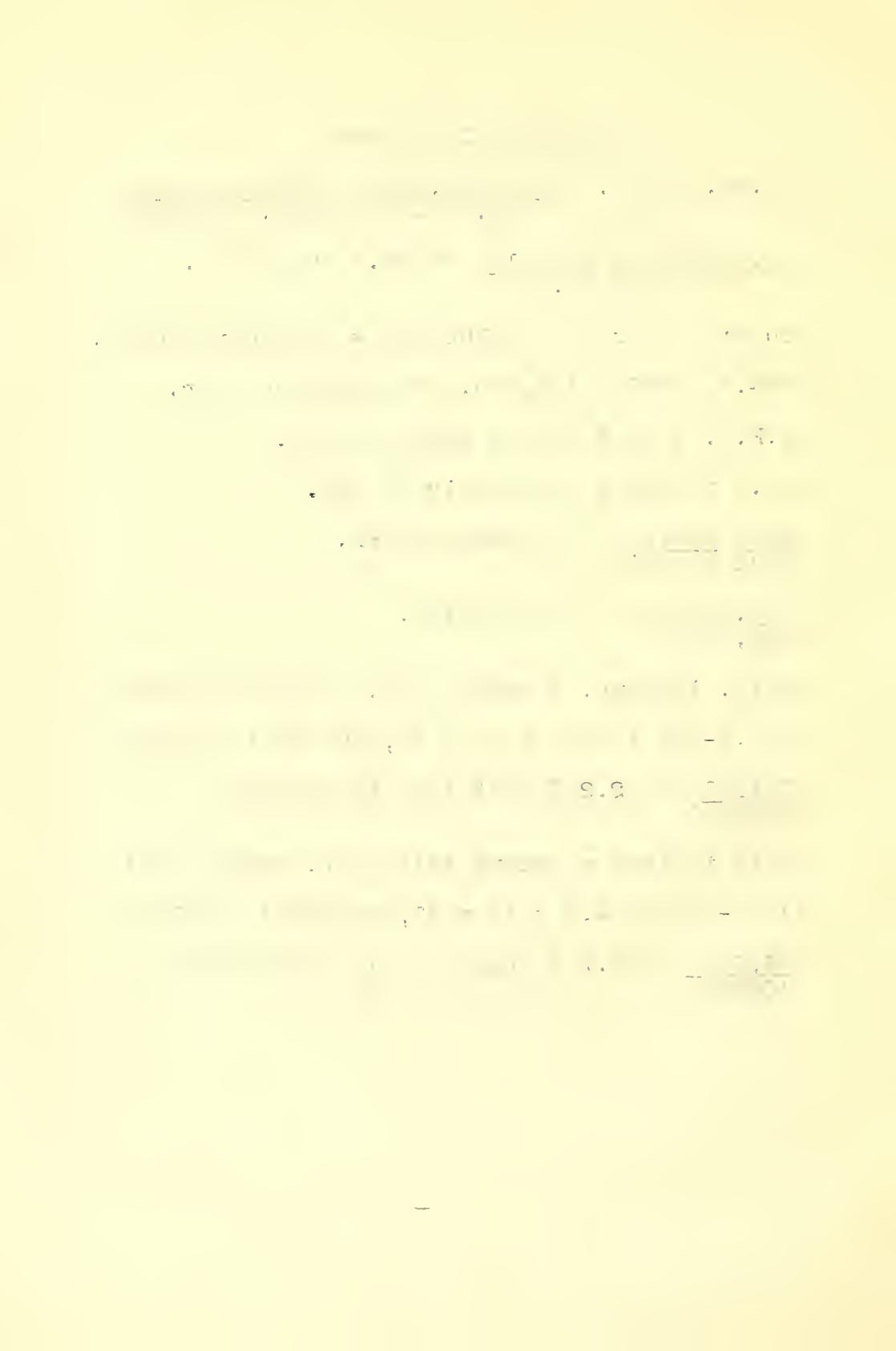
$$(82.5-53) \times 99.5 \times 12 = 35,160 \text{ BTU in Exhaust}$$

$$\frac{35,160}{158,000} = 22.8 \% \text{ heat lost in Exhaust}$$

$$\text{Diff in temp} \times \text{Jacket water /hr.} = \text{BTU jacket}$$

$$(102 - 53) \times 74.5 \times 12 = 43,800 \text{ BTU in Jacket}$$

$$\frac{43,800}{158000} = 27.7 \% \text{ heat lost in Jacket water}$$



PART FOUR

CONCLUSIONS

The heat of the exhaust gas as calculated rationally was about ten per-cent lower throughout both runs than that obtained by means of the calorimeter. This shows that either the mean specific heat or the temperature difference or both were assumed incorrectly.

Assuming that the exhaust temperature was 900 deg.F., the mean specific heat of the gas should have been assumed as 0.312, or if the mean specific heat was correct at 0.245, the temperature of the exhaust gas should have been assumed as 1250 deg.F.

